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Chemical and antioxidant parameters of dried forms of ginger rhizomes

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ABSTRACT

There are various products that can be obtained from ginger (*Zingiber officinale* Roscoe) rhizomes, such as dried products, being difficult to choose the best option for antioxidant purposes. In this study, three different dried forms of ginger rhizomes (freshly dried, dried and powder dried) were characterized in terms of chemical composition including individual profiles in sugars, organic acids, fatty acids, tocopherols, and antioxidants (phenolics and flavonoids). The *in vitro* antioxidant properties (free radicals scavenging activity, reducing power and lipid peroxidation inhibition) of their methanolic extracts were also evaluated. The results of this study indicate that the ginger form has significant influence in chemical and antioxidant parameters of the plant; dried ginger (DG) proved to be the best choice. Overall, this study could help the consumer in the selection of the most suitable option regarding antioxidant purposes.

1. Introduction

Phytochemicals are biological active compounds occurred from plants. Recently, there has been growing interest in the useful effects of plant phytochemicals and their impact for the maintenance of health and prevention of disease (Gruenwald et al., 2010; Kim et al., 2012). Spices are also rich sources of phytochemicals (Das et al., 2012) and, particularly, *Zingiber officinale* Roscoe (Ginger) has been used as a spice and as natural additive for more than 2000 years (Bartley and Jacobs, 2000). Ginger belongs to the family Zingiberaceae and it is cultivated in many countries and commercialized to other parts of the world. Its dried rhizomes are consumed as a spice and flavouring agent and are attributed to have many medicinal properties (Gupta, 2008).

Recently, ginger has received growing interest because of its anti-inflammatory (Minghetti et al., 2007) and antidiabetic (Afshari et al., 2007) properties. Pharmacological research also revealed that ginger has anticancer, chemopreventive and chemotherapeutic effects on a variety of tumor cell lines and on animal models (Shukla and Singh, 2007; Cheng et al., 2011). The majority of the studies highlight ginger antioxidant activity (El-Ghorab et al., 2010; Mesomo et al., 2012; Oboh et al., 2012), related to the prevention of a number of diseases (Adel and Prakash, 2010; Gupta and Sharma, 2014; Liu et al., 2014; Przygodzka et al., 2014).

However, the content in bioactive compounds can be influenced by several factors including growing conditions, climate, time of harvesting, and post-harvesting factors (e.g., storage conditions and processing), and varies not only in different parts of the plant but also from country to country (Masullo et al., 2015). An important factor in dry plants is the dehydration process. The most generalized used methods are shade drying (natural drying) and hot air drying, because of their lower cost in comparison with other dehydration processes. Nonetheless, natural drying is not suitable to handle large quantities of material, and might compromise the quality standards (Soysal and Öztekin, 2001), namely in what concerns to contamination or adulteration of the herbal products (Pinela et al., 2011).

The reduction of the moisture content inherent to drying processes is normally related with a microbial growth inhibition and prevention of some biochemical modifications, however, it also promotes a loss of aroma and changes in nutritional, physical (Phoungchandang and Saentaweesuk, 2011; Pinela et al., 2011), and antioxidant (Chan et al., 2009) properties.

There is available in the market a huge diversity of plant formulations, being desirable to know the most adequate form for each specific benefit (Pereira et al., 2014). For example, ginger rhizomes

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are commercially available at the natural stage (fresh vegetables without processing), but also in concentrated ginger powders, and dried products (Phoungchandang and Saentaweesuk, 2011).

Due to the absence of studies comparing ginger forms available for commercialization, it is hard to choose the best option for consumption and for further scientific works. Therefore, the aim of the present study was to characterize chemical and antioxidant parameters of three different forms of ginger rhizomes available in market, and provide consumers with a comparative overview to guide their choice.

2. Material and methods

2.1. Samples and sample's preparation

Different forms of *Zingiber officinalis* rhizomes (fresh ginger, dried ginger- DG and powder dried ginger- PDG) were purchased from the local market. Fresh ginger was washed, cleaned, cuted into small pieces and air-dried (FDG) under constant weight. FDG and DG samples (obtained after a natural shade drying process) were further reduced to a fine dried powder for subsequent analyses.

2.2. Standards and reagents

The HPLC-grade solvents ethyl acetate (99.8%), n-hexane (97%) and acetonitrile (99.9%) were purchased from Fisher Scientific (Lisbon, Portugal). The standard 47885-U (fatty acids methyl ester- FAME mixture), L-ascorbic acid, sugar standards (D(−)-fructose, D(+)-glucose, D(+)-melezitose, D(+)-sucrose and D(+)-trehalose) and the standard used in the antioxidant activity assays (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid; trolox) were from Sigma (St. Louis, MO, USA). Tocopherol standards (α-, β-, γ-, and δ-isoforms) and the racemic tocol (50 mg/mL) used as internal standard in tocopherol's analysis were obtained from Matreya (Pleasant Gap, PA, USA). 2,2-Diphenyl-1-picrylhydrazyl (DPPH), used in antioxidant activity assays (free radicals scavenging activity), was obtained from Alfa Aesar (Ward Hill, MA, USA). Water was treated in a Milli-Q water purification system (TGI Pure Water Systems, Greenville, SC, USA).

2.3. Chemical parameters

2.3.1. Sugars.

Melezitose was used as the internal standard (IS) being incorporated in the extraction procedure previously described by the authors (Guimarães et al., 2013a). The high performance liquid chromatography (HPLC) equipment (Knauer Smartline, Berlin, Germany) included a pump, a degasser system, and a refraction index (RI) detector. An auto-sampler (AS-2057 Jasco, Easton, MD, USA) and a data analyzer Software (Clarity 2.4 DataApex) were also used. The chromatographic separation conditions were as follows: Eurospher 100–5 NH_2 column (4.6 × 250 mm, 5 μm, Knauer, Berlin, Germany) at 35 °C; acetonitrile/deionized water, 70:30 (v/v), as mobile phase, at 1 mL/min. The identification was performed by comparison with standards, and the quantification was carried out by using the internal standard method. The results were expressed in g per 100 g of dry weight.

2.3.2. Organic acids

The extraction procedure was previously described by the authors (Pereira et al., 2013). The equipment was a Shimadzu 20A series UFLC (Shimadzu Corporation, Kyoto, Japan). The chromatographic separation conditions were as follows: Sphere Clone (Phenomenex, Torrance, CA, USA) reverse phase C_{18} column (5 μm, 250 mm × 4.6 mm i.d.), at 35 °C; sulphuric acid (3.6 mM) as mobile phase at 0.8 mL/min. It was used a photodiode array detector (PDA) at 215 and 245 nm (for ascorbic acid) as preferred wavelengths. The quantification was performed by comparison of the area of the peaks recorded at 215 nm with calibration curves of commercial standards. The results were expressed in g per 100 g of dry weight.

2.3.3. Fatty acids

The extraction procedure was previously described by the authors (Guimarães et al., 2013a). The gas-chromatography equipment (DANI GC 1000, Contone, Switzerland) included a split/splitless injector, a flame ionization detector (FID) at 260 °C, and a CSW 1.7 Software (DataApex 1.7). The chromatographic separation conditions were as follows: Macherey–Nagel (Düren, Germany) column (50% cyanopropyl-methyl-50% phenyl-methylpolysiloxane, 30 m × 0.32 mm i.d. × 0.25 μm d_f); the initial temperature of the column was 50 °C, held for 2 min, then a 30 °C/min ramp to 125 °C, 5 °C/min ramp to 160 °C, 20 °C/min ramp to 180 °C, 3 °C/min ramp to 200 °C, 20 °C/min ramp to 220 °C and held for 15 min; carrier gas (hydrogen) at 4.0 mL/ min (0.61 bar), measured at 50 °C; split injection (1:40) at 250 °C. The identification was performed by comparison of the relative retention times of samples FAME peaks with standards. The results were expressed in g/100 g fat.

2.3.4. Tocopherols

Racemic tocol was used as IS, being incorporated in the extraction procedure previously described by the authors (Guimarães et al., 2013a). The HPLC equipment was described in Section 2.3.1., but with a fluorescence detector (FP-2020; Jasco, Easton, MD, USA) programmed for excitation at 290 nm and emission at 330 nm. The chromatographic separation conditions were as follows: a Polyamide II (5 μm, 250 mm × 4.6 mm i.d.) normal- phase column (YMC Waters, Dinslaken, Germany) at 35 °C; a mixture of n-hexane and ethyl acetate (70:30, v/v) as mobile phase, at 1 mL/min. The identification was performed by comparison with standards, and the quantification was based on calibration curves obtained from commercial standards using the IS method. The results were expressed in mg per 100 g of dry weight.

2.4. Antioxidant parameters

2.4.1. Extraction procedure.

Each sample of *Zingiber officinalis* rhizomes (1 g) was extracted submitted to a solid-liquid extraction with 25 mL of methanol (25 °C at 150 rpm) during 1 h. After filtration with Whatman N° 4 paper, the obtained residue was re-extracted in the same conditions of the ones previously used. The methanol was removed at 40 °C (rotary evaporator Büchi R-210) and the remaining extracts were re-dissolved in methanol (final concentration, 5 mg/mL). These final solutions were further diluted to different concentrations to be used in the subsequent assays.

2.4.2. Phenolics and flavonoids

Total phenolics were estimated according with Wolfe et al. (2003). Briefly, Folin Ciocalteu reagent (5 mL, diluted with water 1:10 v/v) and sodium carbonate (75 g/L, 4 mL) were added to the extract solutions (1 mL), vortexed for 15 s and allowed to stand for 30 min at 40 °C. The absorbance was measured at 765 nm and gallic acid was used to obtain the standard curve (0.05–0.8 mM; $y = 1.9799x + 0.0299$; $R^2 = 0.9997$). The results were expressed as mg of gallic acid equivalents (GAEs) per g of extract.

Total flavonoids were estimated according with Jia et al. (1999). Briefly, the extract solutions (0.5 mL) were mixed with distilled water (2 mL) and $NaNO_2$ solution (5%, 0.15 mL), for 6 min. $AlCl_3$ solution (10%, 0.15 mL) was added for 6 min and, then, NaOH solution (4%, 2 mL) was added. Immediately, distilled water was also added up to the final volume of 5 mL and the mixture was allowed to